AMBIENT AIR QUALITY IN THE SARNIA AREA

ANNUAL REPORT 1987

JUNE 1989

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Environment Ontario

Jim Bradley
Minister

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ISSN: 0823-5163

AMBIENT AIR QUALITY
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Technical Support Section
Southwestern Region

JUNE 1989

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SUMMARY

Ambient air quality monitoring in the Sarnia area during 1987 revealed that levels of most air pollutants are normally low. Levels of total suspended particulates were remarkably low with the exception of elevated levels near Holmes Foundry Limited. The monitoring results indicated that these elevated levels of suspended particulates are usually associated with foundry emissions.

Levels of sulphur dioxide were satisfactory and the Air Pollution Index remained below the Advisory level of 32. Levels of carbon monoxide, hydrogen sulphide and mercaptans and oxides of nitrogen in Sarnia continue to compare favourably with levels experienced by other communities in Ontario. In Sarnia, there were no measurements of these pollutants above the criteria for desirable ambient air quality. South of Courtright there were 3 hourly sulphur dioxide values above the 1-hour criterion for desirable ambient air quality. The excursions could not be linked to a specific source of emission due to calm wind conditions but emissions from power generating plants would be the most likely cause.

The criterion for ozone was exceeded in Sarnia and at the rural monitoring site east of Sarnia. The excursions were primarily attributable to the long-range transport of ozone into the Sarnia area. The U.S. Environmental Protection Agency is requiring individual states to implement control strategies that will ensure attainment of the U.S. primary air quality standard. Ontario is also developing control strategies for ozone. New, more restrictive emission standards for Canadian cars starting with 1988 model years should appreciably reduce ozone precursor chemicals.

Fluoride levels south of Courtright decreased appreciably in 1987. The decrease may be associated with steps to reduce emissions of fluorides from the Canadian Industries Limited operations.

INTRODUCTION

The ambient air monitoring network of the Ministry of the Environment measures the levels of a number of pollutants that may directly or indirectly adversely affect health, vegetation or the enjoyment of property. Data on levels of pollutants are compared with Ontario's criteria for desirable ambient air quality. Thus, excursions above these criteria reflect undesirable conditions. Data are also used to determine trends in air quality and therefore, the effectiveness of pollution abatement, as well as to provide information on the effect of specific sources of pollutants and to formulate strategies to control pollution.

Ontario Hydro, the Lambton Industrial Society and private industry also operate ambient air monitors in the Sarnia area. The Ministry also conducts special air monitoring surveys for short periods of time as well as conducting phytotoxicology surveys to determine the effects of air pollutants on vegetation. The results of the special surveys and monitoring by other groups are not contained in this report.

Emissions from industrial and other stationary sources of pollutants in Ontario are regulated by this Ministry through a Certificate of Approval. In the Sarnia area, there is a special control strategy for sulphur dioxide. This special control strategy requires major sources of sulphur dioxide to provide supplementary control if the ambient levels of sulphur dioxide approach the 24-hour criterion for desirable ambient air quality.

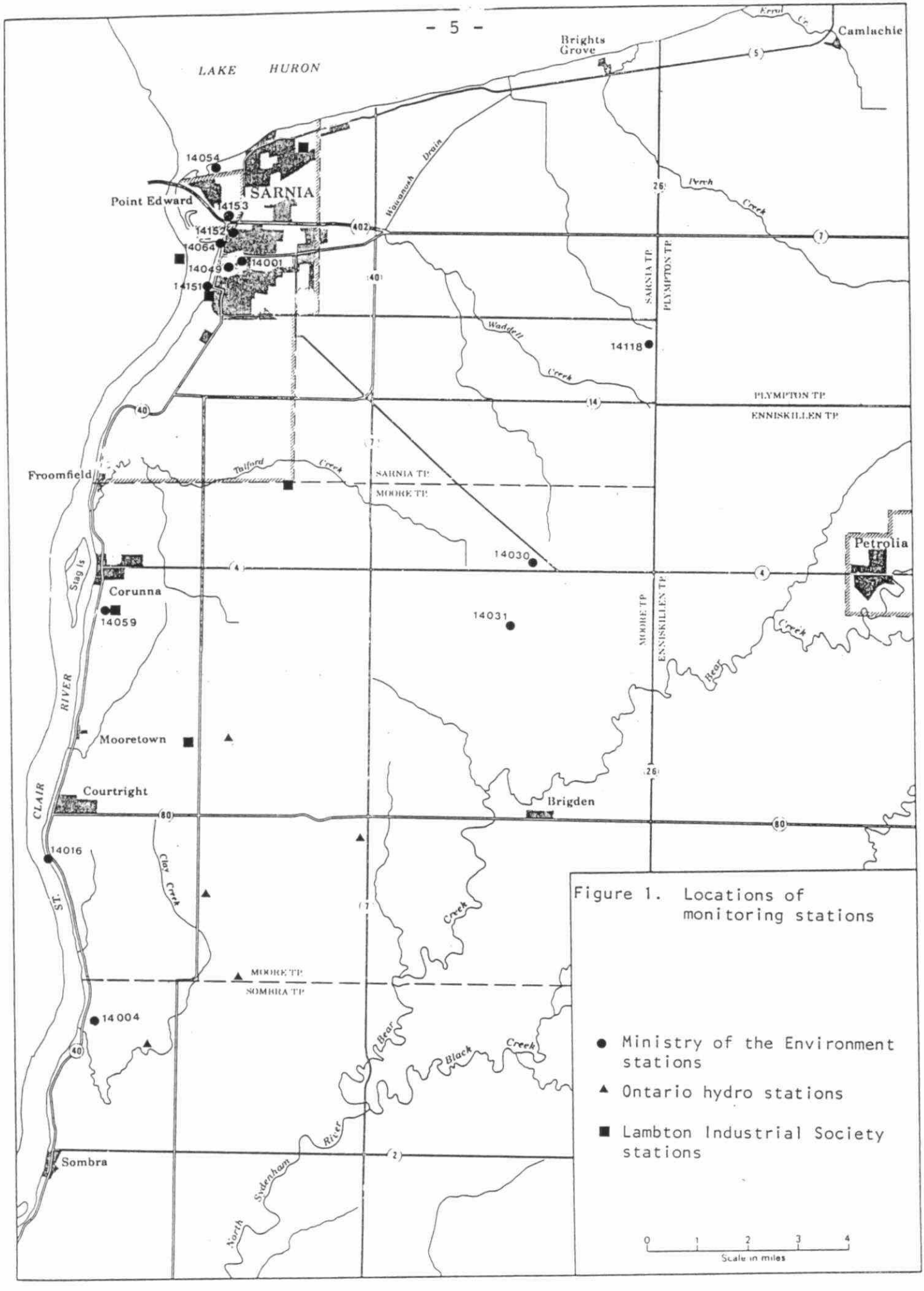
DESCRIPTION OF MONITORING NETWORK

Continuous and intermittent monitors for determining levels of pollutants in ambient air are maintained by the Ministry at sites dispersed throughout the Sarnia area. However, monitoring is more intensive in the area of downtown Sarnia because it has a higher potential for elevated levels of pollutants than most other areas in Lambton County. This higher potential is a result of the downtown area being affected by emissions from industries and power generating plants to the south, as well as dense vehicular traffic and commercial establishments in the downtown core. The industries and power generating plants to the south of Sarnia tend to be located along the St. Clair River and plumes from different sources of emissions can create an additive impact when they impinge on the downtown area. Furthermore, the taller buildings situated in the downtown core affect wind currents and may bring pollutants from aloft down towards ground level.

In 1987, the Ministry added two new monitoring stations in the vicinity of Holmes Foundry to determine the impact of foundry emissions on suspended particulate levels.

The location of the Ministry's fixed monitoring sites are illustrated in Figure 1. Also included in Figure 1 are the locations of monitoring sites of Ontario Hydro and the Lambton Industrial Society. Specific Ministry locations and the pollutants monitored are listed in Table A1, Appendix 1.

Criteria for desirable ambient air quality and the supporting rationale for the establishment of these criteria appear in Table A2, Appendix 1.


LAKE HURON
Brights Grove
Camlachie
Errol Cr.
14054
SARNIA
Point Edward
14153
14152
14064
14049
14001
14151
Wawanosh Drain
Perch Creek
SARNIA TP
PLYMPTON TP
14118
Waddell Creek
PLYMPTON TP
ENNISKILLEN TP
Froomfield
Talford Creek
SARNIA TP
MOORE TP
Petrolia
14030
Stag Is.
Corunna
14059
14031
MOORE TP
ENNISKILLEN TP
Bear Creek
CLAIR RIVER
Mooretown
Courtright
Brigden
14016
ST. CLAIR
Clay Creek
Creek
MOORE TP
SOMBRA TP
14004
Bear Creek
Black Creek
Sombra
North Sydenham River
Figure 1. Locations of monitoring stations
Ministry of the Environment stations
Ontario hydro stations
Lambton Industrial Society stations
0 1 2 3 4
Scale in miles

METEOROLOGICAL DATA

Meteorological data are utilized in predicting the stability of the atmosphere which affects the dispersion of pollutants. These data also assist in identifying sources of pollutants and in validating mathematical models designed to predict the dispersion of air pollutants.

The main meteorological tower in the area is located at station 14016 immediately south of Courtright. Wind speed and direction are measured at 10 metres, 30 metres and 92 metres above ground level. In addition, ambient temperature is measured at the 10-metre level and the gradients in temperature between the 10-metre level and the 30- and 90-metre levels are determined. These meteorological data are transmitted to Toronto by a telemetry system. Meteorologists utilize the data to forecast the stability of the atmosphere. This forecasting feature is an intrinsic part of the Air Pollution Index and the Lambton Industrial Meteorological Alert, both discussed later in this report.

Meteorological data from station 14016 have been used in computing the average concentrations of some pollutants for specific wind directions and in determining the number of hours that the criteria for ozone have been exceeded for different wind directions.

A summary of the frequency of winds for different directions at the 30-metre level of station 14016 appears in Table A3, Appendix 2. The data indicate that the prevailing winds are from the south.

MONITORING PROGRAM AND RESULTS

PARTICULATES

Primary sources of man-caused emissions of particulates to the atmosphere are vehicular traffic, materials handling and combustion processes. Wind-blown particulates from open fields, sand and coal piles, roadways and roofs are also significant sources.

Measurements for particulates are reported as total suspended particulates and soiling index. Total suspended particulates are determined by drawing measured volumes of air through a pre-weighed filter for 24-hours and subsequently weighing the quantity of particulates collected on the filter. Soiling index is measured by determining the difference in the amount of light that is transmitted through a filter before and after ambient air is drawn through the filter for 1 hour. The amount of light transmitted through the filter is affected by quantity, size, shape and opaqueness of particulates retained on the filter. Soiling index can be correlated to levels of suspended particulates and can be determined without the time-consuming laboratory analysis required for determining concentrations of total suspended particulates. For these reasons, soiling index is used as a substitute for suspended particulate values when data are required quickly such as in the Air Pollution Index.

Total Suspended Particulates

Two criteria for desirable ambient air quality exist for total suspended particulate matter. One is 120 micrograms of suspended particulates per cubic meter of air (ug/m^3) averaged over a 24-hour period. The other is an annual geometric mean of 60 ug/m^3. The criterion for 24 hours is based on impairment of visibility and adverse health effects associated with combined concentrations of sulphur dioxide and suspended particulates. The annual criterion is based on public awareness of suspended particulates and property damage.

During 1987 total suspended particulates were sampled at 10 sites in the Sarnia area. At 7 of the sites a 24-hour sample was collected on an every-sixth-day schedule for the year. At two new sites near Holmes Foundry sampling was conducted on an every-three-day schedule while at another site, station 14016 near Courtright, sampling was conducted on a daily basis. The national monitoring network of the United States and Canada operate on the same every-sixth-day sampling schedule for suspended particulate matter. The Ministry operates the daily schedule at station 14016 to evaluate how representative the every-sixth-day schedule is of the complete year. The 1987 data indicate that the every-sixth-day schedule was reasonably representative of conditions throughout 1987.

With the exception of the two new monitoring stations located near Holmes Foundry, 1987 levels of suspended particulates were low in the Sarnia area and there were very few excursions above the 24-hour criterion for desirable ambient air quality. The low levels were similar to those experienced at monitoring stations in operation in 1985 and 1986.

The two new Hi-Vol samplers located near Holmes Foundry collected samples that contained greater concentrations of total suspended particulates than the other monitoring stations in the Sarnia area. The higher levels of total suspended particulates are linked to emissions from Holmes Foundry by evaluating the data with wind direction and increases in iron, manganese and free carbon concentrations. Iron and manganese are reported in the literature as good elements to trace foundry emissions and free carbon is also emitted by foundry operations.

The emissions from Holmes Foundry impacted station 14152, located at the City of Sarnia police station, more severely than station 14153, located immediately north of Highway 402. Besides the 10 samples collected at station 14152 that exceeded the 24-hour criterion, the annual criterion was also exceeded at station 14152. In general, the emissions from the foundry cause a very localized effect with little or no impact detectable at stations slightly farther from the foundry than stations 14152 and 14153. For example, station 14064 located in Centennial Park is not normally affected by the foundry emissions. The 1987 annual geometric mean concentration for total suspended particulates was 42 ug/m^3 at station 14064 compared to 68 ug/m^3 at station 14152. The annual criterion of 60 ug/m^3 was exceeded only at station 14152 and not at any of the other 9 monitoring stations in the Sarnia area.

A summary of 1987 data for total suspended particulate matter appears in Table 1. Figure 2 shows the annual geometric means and the frequencies of excursions above the 24-hour criterion for 1987 at the approximate locations of the monitoring sites.

The trend of improved levels of total suspended particulate matter is illustrated by Figures 3 and 4. Figure 3 shows that for 5 monitoring sites (1) in operation since 1972 the average annual geometric mean has been lowered by more than 50% while Figure 4 shows that the frequencies of excursions above the 24-hour criterion have been reduced by over 90 percent.

In general levels of total suspended particulates in the Sarnia area compare very favourable with levels experienced in other areas of Ontario. Except for the results for stations near Holmes Foundry, the results for 1987 are low which can be attributed to both better control of emissions and favourable meteorology.

(1) The stations are 14001, 14016, 14054, 14064 and 14151. Station 14064 replaced station 14049 in 1978 but comparison studies revealed that the levels of suspended particulates were similar at both sites.

Table 1. Summary of 1987 data for total suspended particulates

Station No.	No. of samples collected	Annual geometric mean (ug/m³)	No. of values greater than 24-hour criterion	Percentage of Values greater than 24 hour criterion
14001	56	37	0	0
14016	339	34	1	0.3
14016-S	55	33	0	0
14030	59	33	1	1.7
14031	56	29	1	1.8
14054	57	40	1	1.8
14059	57	35	0	0
14064	59	42	1	1.7
14151	60	47	2	3.3
14152	87	68	10	11.5
14153	81	50	6	7.4

Note: Data for station 14016-S are every-sixth-day sampling results extracted from the daily sampling data for station 14016.

The annual criterion for desirable ambient air quality is 60 ug/m³.

The 24-hour criterion for desirable ambient air quality is 120 ug/m³.

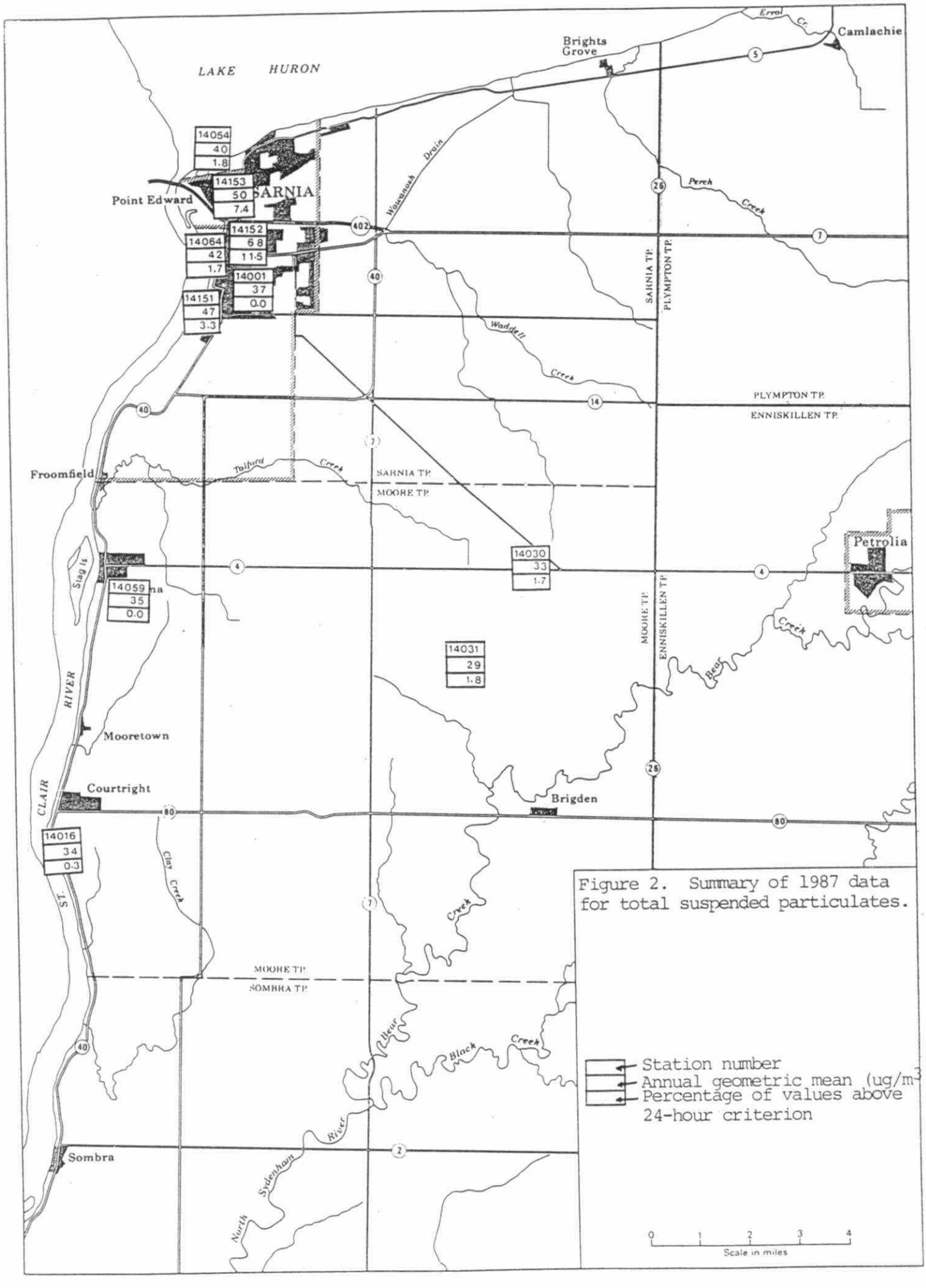


Figure 2. Summary of 1987 data for total suspended particulates.

Figure 3. Trend in annual levels of total suspended particulates based on data averaged for five monitoring stations.

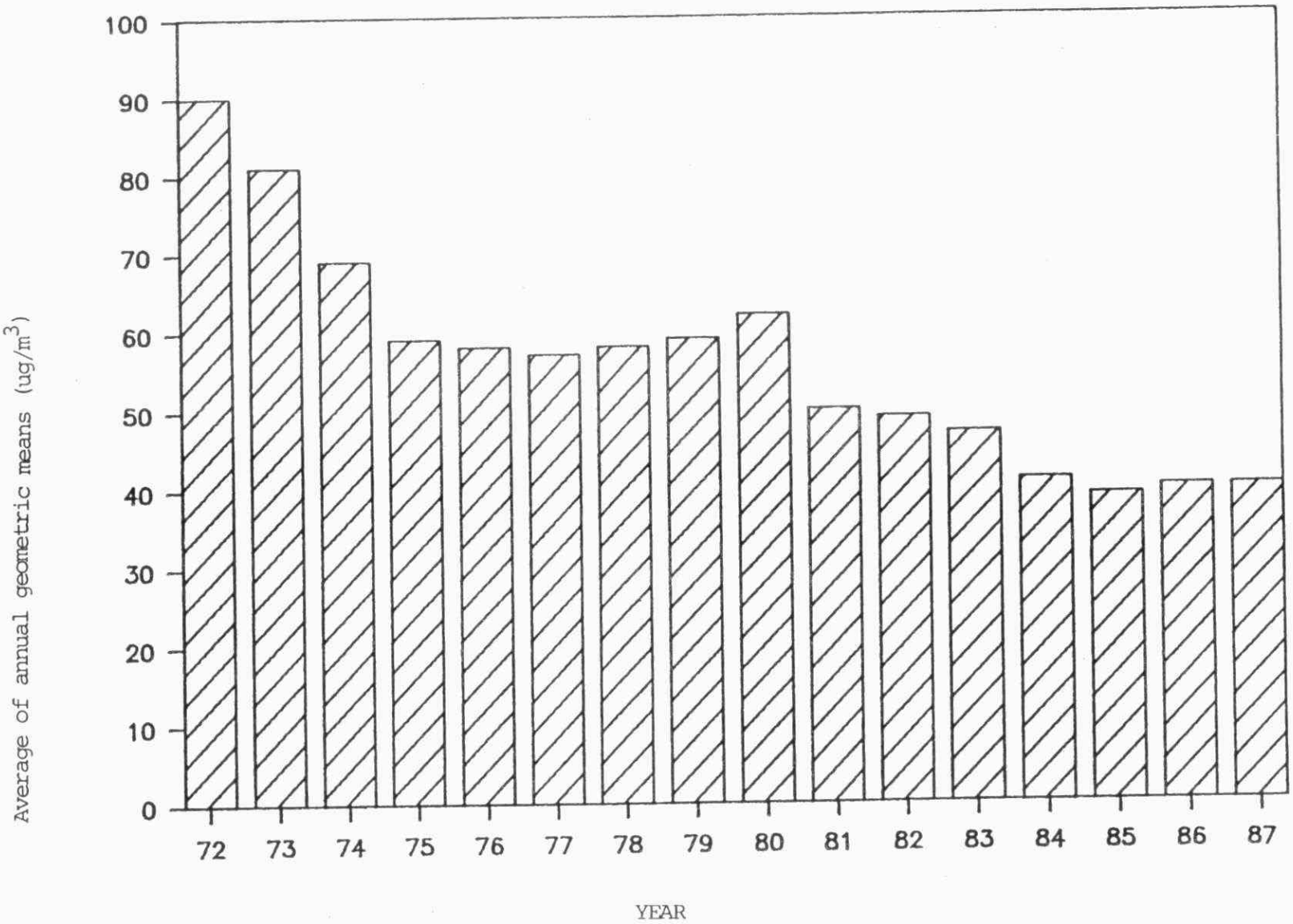
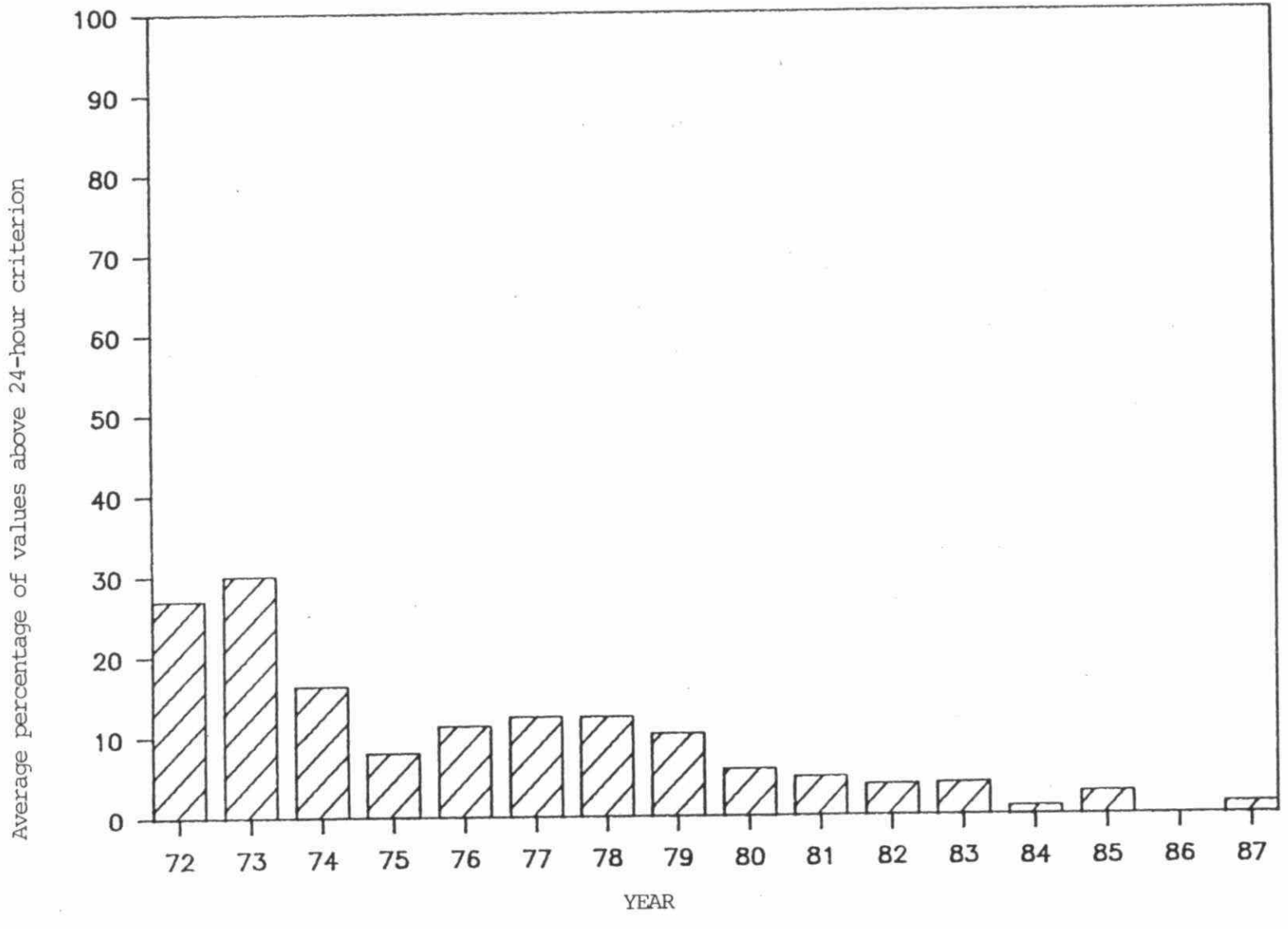


Figure 4. Trend in excursions above 24-hour criterion for total suspended particulate based on data from five monitoring stations



Chemical Analysis of Suspended Particulates

Samples of suspended particulates collected at 6 stations in the Sarnia area during 1987 were analyzed for cadmium, chromium, copper, iron, lead, manganese, nickel and vanadium. For four of these stations samples were also analyzed for nitrates and sulphates. For two stations (14152 and 14153) samples were analyzed for total carbon, free carbon and carbonate. A summary of data from 1976 through 1987 for these constituents is contained in Table A4, Appendix 3.

A review of Table A4 reveals that iron and manganese levels were appreciably greater at stations 14152 and 14153 than at the other stations for which samples were analyzed for these elements. As mentioned previously iron and manganese are emitted from iron foundries and the results provide valuable information linking elevated total suspended particulate levels to foundry emissions.

Data for sulphates are erroneously high, based on the findings of several studies of the sampling method utilized by the Ministry. The problem may be rectified by using a different filter media and the Ministry is investigating the feasibility of changing filter media.

Criteria for desirable ambient air quality exist for cadmium, chromium, lead, nickel and vanadium. There have been no values above the criteria and in general, the concentrations of the various metals have been low.

SULPHUR OXIDES

Combustion of sulphur-containing fuels comprises the predominant source of man-made emissions of sulphur oxides. In the Sarnia area, large quantities of these fuels are consumed by power-generating plants in Michigan and Ontario and by petroleum and petrochemical industries located south of downtown Sarnia.

The Ministry of the Environment monitors sulphur oxides in the Sarnia area using continuous analyzers for gaseous sulphur dioxide and by analyzing suspended particulate matter for sulphate.

Throughout 1987 the Ministry measured gaseous sulphur dioxide at station 14016 south of Courtright and at station 14064 in Centennial Park, downtown Sarnia. There were 11 other sites where monitors providing continuous measurements of sulphur dioxide were operated by Ontario Hydro, the Lambton Industrial Society or private industry. Data for these sites are not included in this report but were utilized to confirm conclusions drawn from the data generated by the Ministry's instruments.

Data are reported as 1-hour average concentrations, 24-hour average concentrations (midnight to midnight) and annual average concentrations. Criteria for desirable ambient air quality are 0.25 parts of sulphur dioxide per million parts of air (ppm) averaged for a 1-hour period, 0.10 ppm averaged for 24 hours and 0.02 ppm as an annual average. The criteria for the 1-hour and annual averages are based on the protection of vegetation while the 24-hour criterion is based on the protection of human health.

The 24-hour and annual criterion were not exceeded in 1987. There were 3 hourly values above the 1-hour criterion at station 14016. These excursions occurred from 11:00 to 13:00 hours on July 15, 1987 during calm wind conditions. No specific source has been identified as the cause of the excursions. This type of excursion can be expected from time-to-time in the early afternoon when inversion conditions break-up and good mixing results in plumes from power generating plants in the area being brought down towards ground level. However, since the 1-hour criterion is based on the protection of vegetation and no damage to vegetation attributable to sulphur dioxide has been detected in the area for many years, the infrequent excursions of the 1-hour criterion are not believed to be creating an environmental problem. Table 2 contains a summary of the 1987 data.

Table 2. Summary of 1987 data for sulphur dioxide

Station No.	Annual average (ppm)	Percentage of Values above criterion		Maximum 1-hour value (ppm)	Maximum 24-hour (daily) value (ppm)
		1-hour	24-hour		
14016	0.00	0.04	0	0.38	0.07
14064	0.01	0.00	0	0.20	0.05

In the past, there was concern about the frequency of excursions in the downtown area of Sarnia above the 24-hour criterion for desirable ambient air quality. This concern resulted in a new regulation called LIMA (1) being implemented in April, 1981. This regulation requires major industrial emitters of sulphur dioxide to provide additional controls either continuously or when required by the Ministry. The Ministry may require industries to provide increased control when meteorological conditions conducive to adverse air quality are likely to persist and sulphur dioxide levels are elevated at specified monitoring sites. The specific monitoring sites consist of two in Sarnia, one in Port Huron and one in Corunna. One site in Sarnia and the sites in Port Huron and Corunna are part of the Lambton Industrial Society's monitoring network. The other site in Sarnia is the Ministry's station 14064, located in Centennial Park.

This control strategy has been very successful. Since the regulation went into effect in 1981, the 24-hour criterion has not been exceeded at the Ministry's monitoring stations, nor has the Air Pollution Index reached the Advisory Level of 32.

Pollution roses for sulphur dioxide measurements appear in Figure 5. The roses were created using data for wind direction and speed from the 30-metre level of station 14016 and concentrations of sulphur dioxide determined at the various stations. The length of the line corresponding to a specific wind direction indicates the average sulphur dioxide concentration when the winds are from that direction. The rose for station 14064, located in downtown Sarnia, reflects appreciably higher levels of sulphur dioxide when winds are blowing from industries located in south Sarnia and farther south. However, since the ambient air quality criteria are met the influence of the local emission sources is not creating an apparent problem.

(1) Lambton Industrial Meteorological Alert

The rose for the station south of Courtright reveals an impact from the emission sources to the north. Any impact from the Detroit Edison St. Clair Power Generating Station located south of the monitoring stations is very minor as is the case for the Lambton Generating Station of Ontario Hydro, located to the south-southwest. However, the monitoring station is located too close to the Lambton Generating Station to measure the main impact of the generating station emissions. The monitoring network of Ontario Hydro has 5 monitoring stations located at distances where maximum impact is anticipated. Levels of sulphur dioxide at these stations were similar to levels at the Ministry station south of Courtright.

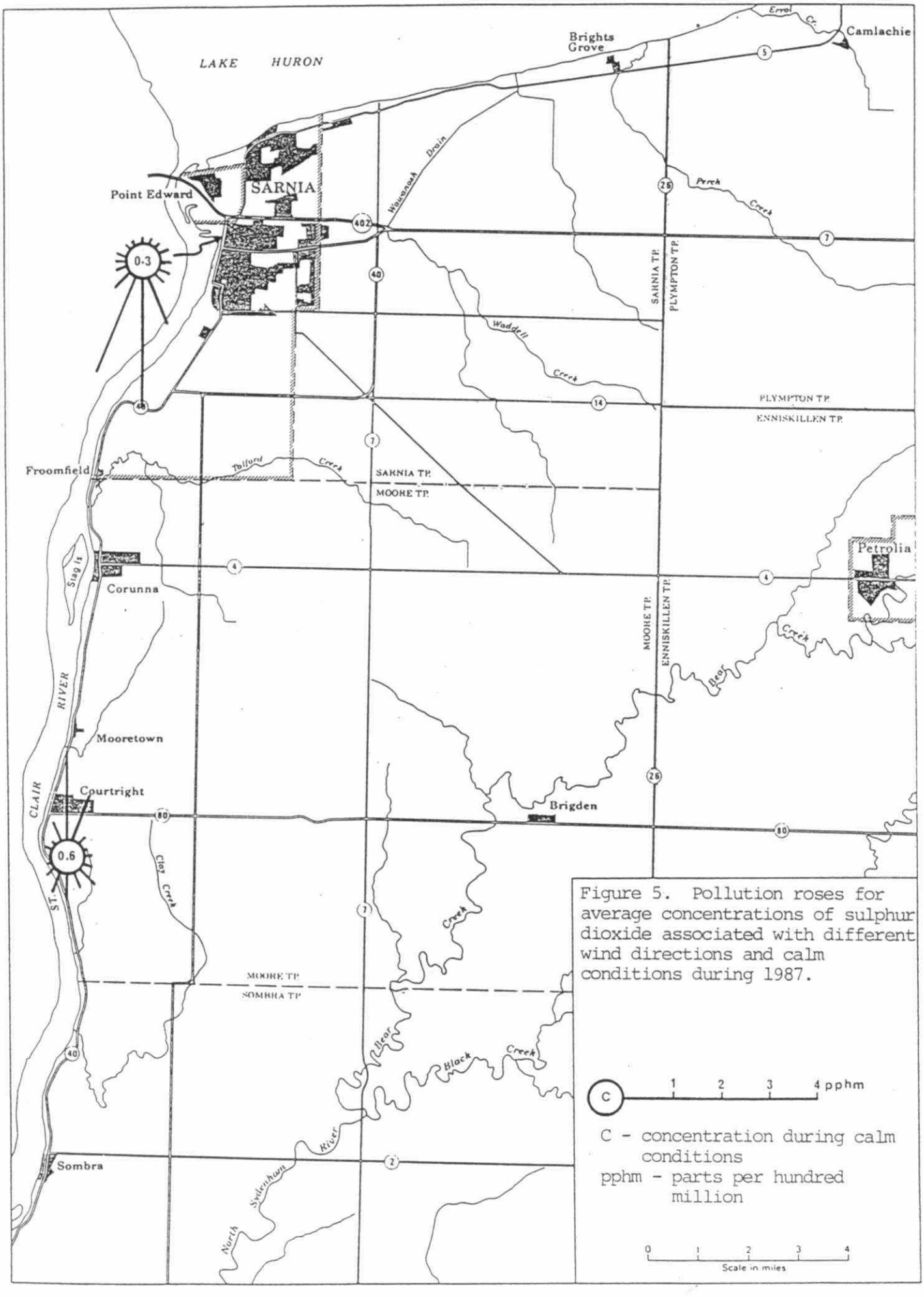


Figure 5. Pollution roses for average concentrations of sulphur dioxide associated with different wind directions and calm conditions during 1987.

AIR POLLUTION INDEX

The Air Pollution Index (API) is a system designed to control or prevent an air pollution episode. Meteorological forecasting and current readings of sulphur dioxide and suspended particulates are utilized to predict the potential for persistence of pollution conditions that are reported as the API. In June 1988 the Air Quality Index was introduced in Sarnia. The AQI includes the API and will be described in future reports.

Data for suspended particulates are provided by the measurement of soiling index and a correlation between concentrations of suspended particulates and soiling index. Hourly values of soiling index and gaseous sulphur dioxide are used to compute 24-hour running averages which are inserted into the following equation.

$$API = 3.02\ (9.75\ COH + 125.95\ SO_2)^{0.76}$$

where: COH is the 24-hour running average for soiling index expressed in units of coefficient of haze. SO_2 is the 24-hour running average for sulphur dioxide expressed in parts per million.

The sulphur dioxide and soiling index data utilized to determine the API for Sarnia are obtained from monitors operated at station 14064 in the downtown core.

API values below 32 are considered acceptable. Values from 32 to 49 are at the Advisory Level and if adverse weather conditions are likely to persist, those responsible for major emissions are advised to prepare to curtail operations. At an API of 50, major emitters may be ordered to curtail operations. At 75, further cutbacks may be required. If the API reaches 100 all contributors of pollution that are not essential to public health and safety may be ordered to cease operations.

The LIMA regulation would result in sulphur dioxide emissions being curtailed well before the API reached 50. A very remote possible exception would be if the soiling index were extremely high and levels of sulphur dioxide were low. Since the API was introduced in Sarnia in December, 1977 it has not reached 50.

Since LIMA was introduced in April, 1981, API levels have been below 32. A favourable comparison between levels in recent years and levels of the initial years of reporting the API can be seen in Figure 6. The annual average for the API was 7.4 in 1987.

TOTAL REDUCED SULPHUR

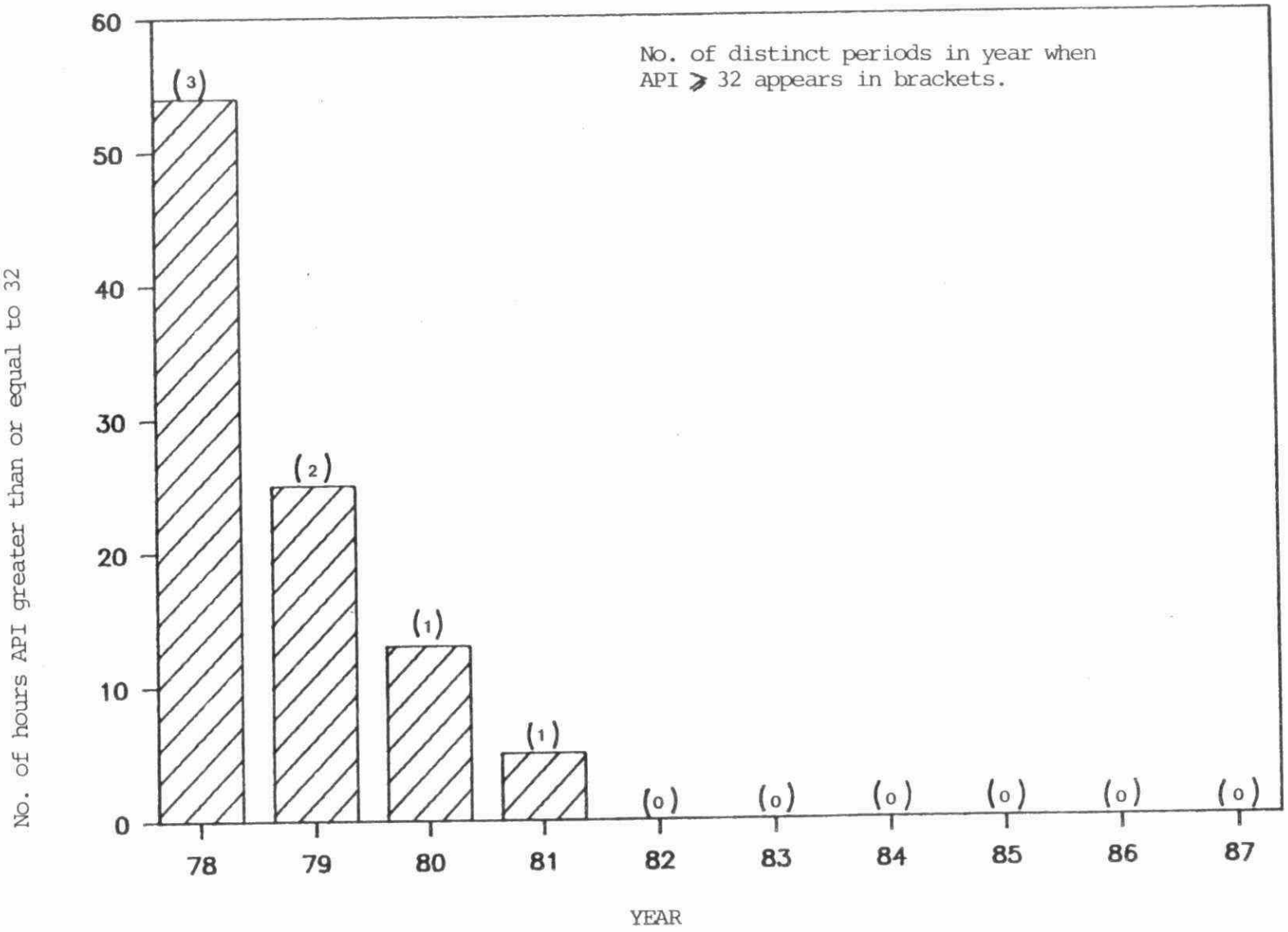
Gaseous total reduced sulphur compounds often exhibit malodours at very low concentrations. Mercaptans are reduced sulphur compounds that contain sulphur and hydrogen and exhibit characteristics similar to hydrogen sulphide. Hydrogen sulphide, also a reduced sulpher compound, is commonly referred to as "rotten egg gas" and many mercaptans are also malodorous at extremely low concentrations.

Both hydrogen sulphide and mercaptans originate in nature from anaerobic decomposition of organic matter containing sulphur. In the Sarnia area, the release of hydrogen sulphide and mercaptans into the atmosphere may result from the processing of petroleum feedstocks containing sulphur.

The criterion established to represent desirable ambient air quality with respect to hydrogen sulphide is 0.02 ppm as an average for 1 hour. This criterion is based on the offensive odours exhibited by this gas. Similarly, the criterion for mercaptans is based on odour and was established as 0.01 ppm averaged for 1 hour and expressed as methyl mercaptan.

Unfortunately, the monitoring instrument in Sarnia does not segregate hydrogen sulphide from mercaptans but determines their combined concentrations and reports these concentrations as hydrogen sulphide. For the purpose of this report the combined concentrations of hydrogen sulphide and mercaptans are compared to the less restrictive hydrogen sulphide criterion.

Figure 6. Trend in Air Pollution Index Levels



During 1987 monitoring was conducted at station 14064 in the downtown area. There were no excursions detected above the 1-hour criterion. A pollution rose, Figure 7, constructed for total reduced sulphur measurements at station 14064 indicates that higher levels occur when winds are blowing towards the monitoring stations from the industrialized area in south Sarnia. A summary of total reduced sulphur data appears in Table A5, Appendix 4.

CARBON MONOXIDE

Combustion processes represent man's major emissions of carbon monoxide. Emissions from motor vehicles are most significant because they occur near ground level and are concentrated in urban areas where the public may be exposed for lengthy periods. Industries and power generating plants normally provide adequate dispersion for their emissions to prevent unsatisfactory levels of carbon monoxide in the ambient air.

The criteria for carbon monoxide, which are based on the protection of human health, are 30 ppm averaged for 1 hour and 13 ppm averaged for any consecutive 8-hour period.

During 1987 carbon monoxide was monitored at station 14064, located in the downtown core at Centennial Park. The criteria for desirable ambient air quality were not exceeded. A summary of data for carbon monoxide measured at station 14064 since 1978 is presented in Table A5, Appendix 4, and illustrates long-term conformity below established criteria.

OXIDES OF NITROGEN

Gaseous oxides of nitrogen are emitted into the atmosphere by man through combustion processes. Nitric oxide and nitrogen dioxide are the gaseous compounds of primary interest.

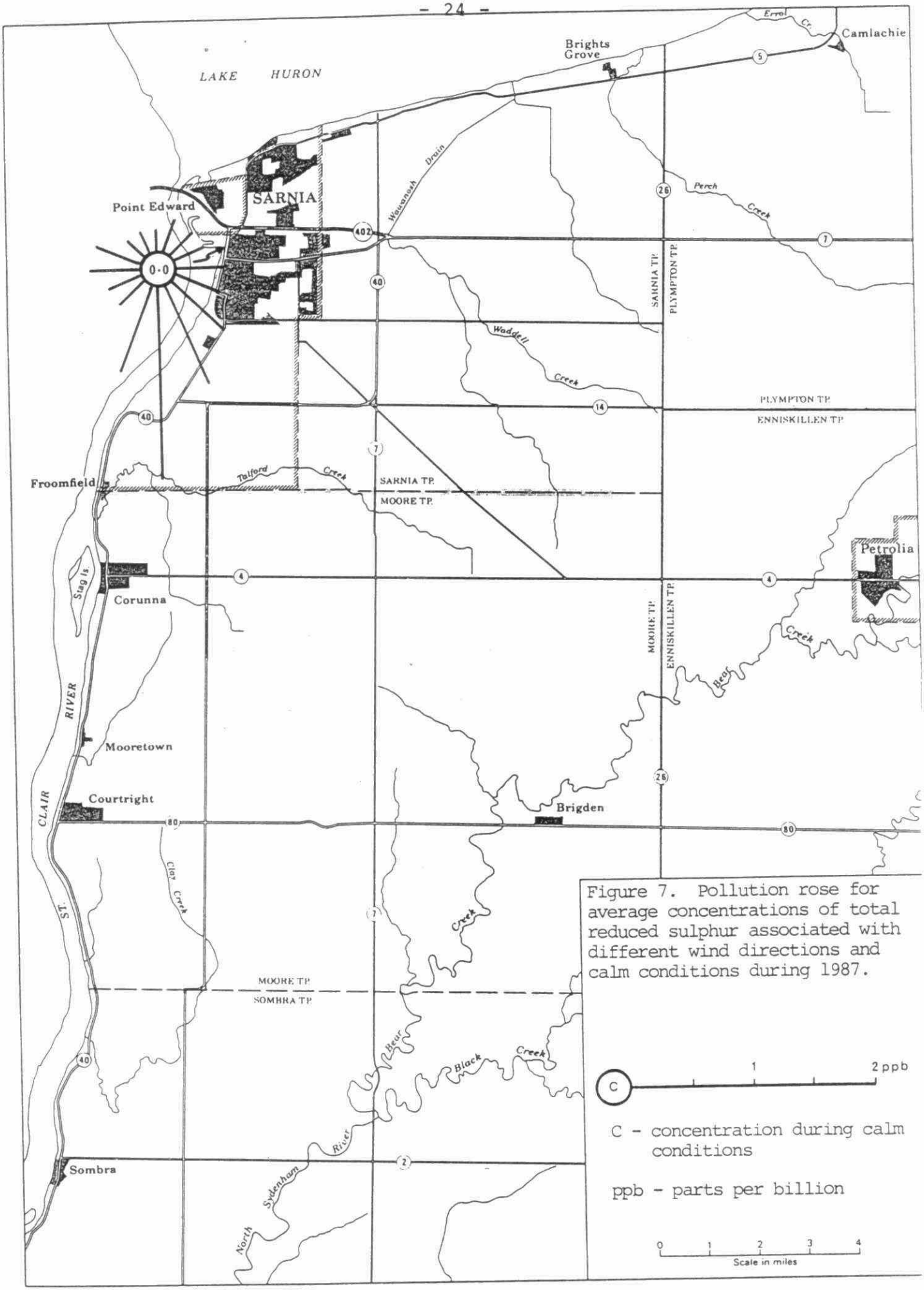


Figure 7. Pollution rose for average concentrations of total reduced sulphur associated with different wind directions and calm conditions during 1987.

Criteria for desirable ambient air quality exist for nitrogen dioxide, but not for nitric oxide or total oxides of nitrogen. The criteria, which are based on offensive odours and the protection of human health, are 0.20 ppm averaged for 1 hour and 0.10 ppm averaged for 24 hours. The 24-hour criterion has not been exceeded at station 14064 where monitoring began in 1978. The 1-hour criterion was not exceeded in 1987 and has only been exceeded once since 1978.

A summary of data for oxides of nitrogen appears in Table A5, Appendix 4. Levels are in ranges typical of communities the size of Sarnia.

Oxides of nitrogen in combination with reactive hydrocarbons and certain meteorological conditions play an important role in the formation of unsatisfactory levels of photochemical oxidants. Also, oxides of nitrogen react to form acids which are part of acidic precipitation. Therefore, consideration is being given to further controls on emissions of oxides of nitrogen. One such control recently implemented is stricter controls for emissions from new cars.

HYDROCARBONS

Emissions from motor vehicles are a primary man-made source of hydrocarbons in ambient air. Other significant man-made sources are incomplete combustion of fuels by industries and power plants, and evaporation losses during the manufacture, use, storage and transportation of materials containing volatile hydrocarbons. Natural phenomena also produce many hydrocarbons of which methane is the most abundant.

Owing to the wide range of effects associated with different hydrocarbons at various concentrations, no criteria for desirable ambient air quality have been established for total hydrocarbons. Instead control is achieved by setting criteria for desirable levels of specific hydrocarbons in ambient air and/or establishing standards which require control of emissions of specific hydrocarbons.

Total hydrocarbons have been measured at station 14064 in Centennial Park since July, 1978. Average levels of total hydrocarbons have been similar each year. A summary of data for hydrocarbons appears in Table A5, Appendix 4.

The Ministry has conducted a number of short term intensified monitoring surveys in the Sarnia area using mobile vans. These surveys have measured numerous specific hydrocarbons at low levels.

OXIDANTS

Oxidants in the ambient air are primarily a result of a series of photochemical reactions and inter-reactions involving oxides of nitrogen and non-methane hydrocarbons. The reactions are promoted by certain meteorological conditions such as warm temperatures and intensive sunshine, resulting in higher levels of oxidants in the spring and summer months.

Throughout 1987 the Ministry monitored oxidants in the form of ozone at station 14064 in the downtown core of Sarnia and at station 14118, situated in a rural setting approximately 10 kilometres east of Sarnia. Ozone normally accounts for 80 to 95 percent of the oxidants present in ambient air. Consequently, with technology for monitoring ozone being more accurate and efficient than for total oxidants, most regulatory agencies monitor for ozone.

Long-range transport of ozone and its precursor chemicals (oxides of nitrogen and hydrocarbons) may account for a very significant portion of local levels of ozone. Long-range transport from distances greater than 200 kilometres has been reported in the literature. Therefore, successful control of oxidants will depend on control strategies implemented in the United States as well as Ontario. The United States and Canada have been jointly addressing the significance of long-range transport of ozone and it precursor chemicals. The United States Environmental Protection Agency required individual states to implement control strategies that would ensure attainment of the

U.S. primary air quality standard for ozone (0.12 ppm, averaged for 1 hour) by December, 1987. However, some states have not met the deadline and extensions have been granted. Ontario has launched a detailed study into oxidants and oxidant control strategies. Also the new emission control requirements for new cars in Canada should have a positive effect on ozone levels by reducing hydrocarbon and oxides of nitrogen emissions.

In addition to ozone formed by photochemical reactions in the troposphere, ground level concentrations of ozone are occasionally increased by ozone from the stratosphere being transported downward. Ozone is naturally produced in minor amounts by lightning.

Ontario's criterion for desirable ambient air quality established for ozone is 80 parts per billion (ppb) averaged for 1 hour. This criterion was established for the protection of vegetation, property and human health. Some oxidant-related effects that are detrimental to health are eye irritation and a decrease in performance during athletic endeavors.

During 1987 the 1-hour criterion was exceeded 44 times at station 14064 and 133 times at station 14118. The more frequent excursions in the rural location of station 14118 is not surprising. With long-range transport accounting for the majority of the elevated ozone values rural locations are subjected to frequent high levels of ozone. In urban areas sometimes the elevated ozone levels imported by long-range transport are reduced through ozone being scavenged by other pollutants more prevalent in urban air than in rural air. A summary of data for ozone appears on Table A6 of Appendix 4.

Pollution roses for 1987 are presented in Figure 8 to show the frequency of the total number of excursions above the criterion associated with different wind directions. At both stations the greatest frequency of excursions are associated with winds from the southwest quadrant. These winds are apt to be associated with the backs of high pressure systems or the area south of low pressure fronts which have weather favourable for photochemical reactions (clear sunny skies and warm temperatures) and which promote long-range transport of oxidants and their precursor chemicals.

FLUORIDES

In the Sarnia area fluorides are emitted into the atmosphere from fossil-fueled power plants where it exists as an impurity in coal, from a fertilizer plant where it occured as a constituent of phosphorus rock and remains in gypsum ponds, and from petroleum refineries where it is used as a catalyst in alkylation.

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluoride present over an extended period of time. A lime-impregnated filter is exposed to ambient air for thirty days and subsequently analyzed for fluoride content. This technique is inexpensive compared to other methods for measuring fluorides. Some fluorides in particulate form are collected on the filters.

Criteria for desirable ambient air quality established for fluoridation rate are based on protection of sensitive vegetation. A criterion of 40 micrograms of fluoride per 100 square centimetres of filter per 30 days (ug F/100 cm^2/30 days) exists for the growing season of April 15 to October 15. A less stringent criterion of 80 ug F/100 cm^2/30 days exists for the period of October 16 to April 14. Since the months of April and October are common to both criteria and fluoridation rate is determined on a monthly basis, excursions above the criteria during these months are determined by comparing fluoridation rate to the average of the two criteria (60 ug F/100 cm^2/30 days).

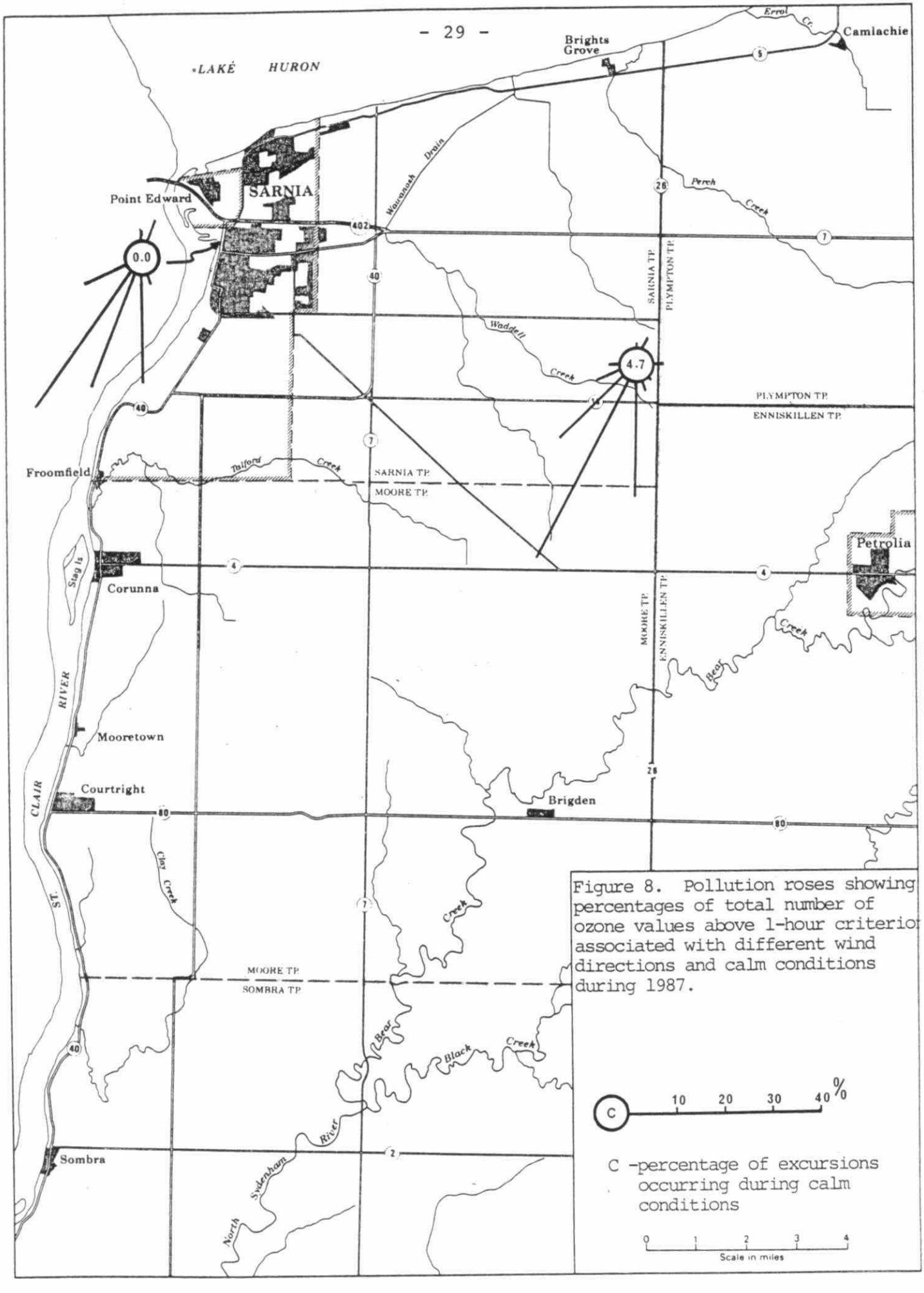


Figure 8. Pollution roses showing percentages of total number of ozone values above 1-hour criterio associated with different wind directions and calm conditions during 1987.

The Ministry monitors fluoridation rate at station 14004, located south of Courtright in the vicinity of the fertilizer complex of Canadian Industries Limited and power generating plants of Ontario Hydro and Detroit Edison. Canadian Industries Limited has maintained a detailed monitoring network for fluoridation rate for many years.

At station 14004 two monthly fluoridation rate values were above the growing season criterion during 1987. The 1987 values were appreciably lower than in any previous year since monitoring began in 1976. Phytotoxicology surveys have not revealed damage to vegetation attributable to fluorides off the property of Canadian Industries Limited. The absence of vegetation damage with the excursions above the growing season criterion may be attributable to the absence of very sensitive vegetation. Table 3 presents the data for fluoridation rate from 1976 through 1987.

The lower fluoridation rates for 1987 compared to previous years may be associated with the shut down of the phosphoric acid plant in 1986 and the reduction of fluorides in gypsum pond water at Canadian Industries Limited.

Table 3. Fluoridation rates measured at station 14004 from 1976 to 1987 (ug F/100 cm^2/30 days)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Average
1976						46	38	74	48	39	21	40	44
1977	42	23	53	32	78	32		79	112	29	104	50	58
1978	83	51	53	57	100	65	94	74	74	57	53	59	68
1979	32	63	25	56	54	64	68	129	89	49	32	26	57
1980	16	23	51	62	61	49	83	84		36	28	31	48
1981	48	48	30	49	69	78	116	122	95	71	55	24	67
1982	48	67	35	35	99	20	50		38	86	35	20	48
1983	17	30	37	42	43	75	60	68	42	73	30	30	46
1984	27	36	45	80	56	61	54	71	43	56	25	30	49
1985	37	27	34	40	39	47	45	89	58	31	50	32	44
1986	27	43	30	46	66	82		57	96	41	29	53	52
1987	25	23	31	33	24	55	37	57	34	20	24	19	32

Note: Underlined values exceeded criteria for desirable ambient air.

APPENDIX I

MONITORING NETWORK

Table A1. Locations of monitoring stations and parameters being monitored.

Station	Location	Parameters Measured	Height of Measurements	Purpose of Stations and Comments
14001	Sarnia General Hospital	Suspended particulates	16 m.	Historical station which has been in operation since 1962. Does not reflect ground level concentrations but does indicate more direct effects of particulates from high stacks and long-range transport.
14004	5 ½ miles south of Courtright	Fluoridation rate	4 m.	Monitors fluorides from fertilizer industry.
14016	1¼ miles south of Courtright	Suspended particulates continuous SO_2, WS, WD, Temp., WS, WD, Temp., WS, WD, Temp., telemetering equipment	1 m. 10 m. 30 m. 92 m.	Monitors suspended particulates and sulphur dioxide in relation to power generating plants. Provides meteorological data required for stability forecasts and air quality interpretations.
14030	R.R. #1 Corunna	Suspended particulates	3 m.	Monitors particulates in the vicinity of Tricil Limited.
14031	R.R. #1 Mooretown	Suspended particulates	3 m.	Monitors particulates in the vicinity of Tricil Limited.
14049	Victoria Street	Continuous SO_2, CO, NO, NO_2, NOx, O_3, total hydrocarbons, suspended particulates	4 m.	Monitored air pollutants in a heavily populated area where traffic, commercial establishments and the heavily industrialized complex south of the monitoring station should be high relative to residential areas. This site was terminated in 1978 and the instruments moved to station 14064.
14054	Sarnia Yacht Club	Suspended particulates	5 m.	Monitors suspended particulates in the north Sarnia-Point Edward area.

Table A1. continued - Locations of monitoring stations and parameters being monitored.

Station	Location	Parameters Measured	Height of Measurements	Purpose of Stations and Comments
14059	Riverbend, Corunna	Suspended particulates	4 m.	Monitors suspended particulates in the residential area of Corunna which is surrounded by industry and generating stations.
140064	Centennial Park Front Street, Sarnia	Continuous SO_2, CO, NO, NO_2, NOx, O_3, total hydrocarbons, total reduced sulphur. 1-hr COH, suspended particulates, telemetering equipment	3 m.	Monitors main air pollutants in an area adjacent to downtown Sarnia and in line with many point sources of pollution located to the south of the downtown area. Provides Air Pollution Index for Sarnia.
14118	Mandaumin, 5 miles west of Wyoming	O_3	5 m.	Monitors ozone levels in a rural location.
14151	Front and David Streets, downtown Sarnia	Suspended particulates	3 m.	Monitors pollutants in commercial area which is also affected by heavily industrialized area to south. Since this is the location of a monitoring station operated by the Lambton Industrial Society, cross checking of monitoring techniques is possible.
14152	Christina and Exmouth Streets, Sarnia	Suspended particulates	5 m.	Monitors particulates near Holmes Foundry Limited.
14153	Mara Street, Point Edward	Suspended particulates	9 m.	Monitors suspended particulates near Holmes Foundry Limited.

Table A2. Desirable ambient air quality criteria established by the Ontario Ministry of the Environment.

Parameter	Desirable ambient air quality criteria	Prime reasons for establishing criteria or monitoring parameter
Carbon monoxide	30 ppm averaged for 1 hour	Protection of human health
	13 ppm averaged for 8 hours	Protection of human health
Fluoridation rate	40 ug of fluorides/100 cm^2 of limed filter paper in 30 days during April 15 to October 15	Protection of vegetation
	80 ug of fluorides/100 cm^2 of limed filter paper in 30 days during October 16 to April 14	Protection of vegetation (less restrictive criterion during the non-growing season)
Hydrocarbons	None	Effects of hydrocarbons vary widely depending on their chemical-physical nature
Hydrogen Sulphide	0.02 ppm averaged for 1 hour	Protection against offensive odours
Mercaptans	0.01 ppm averaged for 1 hour	Protection against offensive odours
Nitric oxide	None	Reacts with oxygen to produce NO_2
Nitrogen dioxide	0.20 ppm averaged for 1 hour	Protection of human health and protection against odours
	0.10 ppm averaged for 24 hours	Protection of human health and protection against odours
Oxides of nitrogen	None	

Table A2. continued
Desirable ambient air quality criteria established by the Ontario Ministry of the Environment.

Parameter	Desirable Ambient Air quality Criteria	Prime reasons for establishing criteria or monitoring parameter
Ozone	0.08 ppm averaged for 1 hour	Protection of vegetation, adverse health effects
Sulphur dioxide	0.25 ppm averaged for 1 hour	Protection of vegetation
	0.10 ppm averaged for 1 day (24 hours)	Protection of human health
	0.02 ppm averaged for 1 year	Protection of vegetation
Suspended particulates	120 ug/m³ averaged for 24 hours	Based on health effects in conjunction with elevated levels of SO_2 and impairment of visibility
	A geometric mean of 60 ug/m³ during 1 year	Based on public awareness of visible pollution
Cadmium in suspended particulates	2.0 ug/m³ averaged for 24 hours	Protection of human health
Lead in suspended particulates	5 ug/m³ averaged for 24 hours	Protection of human health
	A geometric mean of 2 ug/m³ over a 30-day period	Protection of human health
Nickel in suspended particulates	2.0 ug/m³ averaged for 24 hours	Protection of vegetation
Vanadium in suspended particulates	2.0 ug/m³ averaged for 24 hours	Protection of human health

APPENDIX 2

METEOROLOGICAL DATA

Table A3. Percent frequencies of wind directions at the 30-metre level of station 14016.

Year	N	NE	E	SE	S	SW	W	NW
1987	12.8	10.8	6.8	7.9	19.1	18.1	10.9	13.7
1986	12.6	8.4	7.6	8.4	18.0	18.9	12.2	14.1
1985	12.2	10.0	5.7	7.2	20.5	19.0	12.7	12.8
1984	12.6	9.8	6.1	8.2	22.1	15.6	11.0	14.7
1983	13.5	10.6	7.5	9.3	18.9	15.6	10.2	14.4
1982	12.1	9.5	5.2	8.9	22.4	16.4	12.6	12.9
1981	13.8	9.9	4.5	7.8	18.6	15.8	11.9	17.7
1980	12.6	8.6	5.6	7.5	20.1	15.1	14.4	16.1
1979	10.7	8.7	6.5	8.9	24.7	14.7	11.9	14.0
1978	13.6	12.7	6.3	6.0	19.0	17.2	11.9	13.3
1977	11.3	9.8	5.3	7.2	18.5	21.2	14.1	12.6
1976	12.2	9.2	3.5	4.7	18.1	20.5	15.1	16.7

APPENDIX 3

PARTICULATES

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1987.

Station and Year	Cadmium			Chromium			Copper			Iron			Lead		
	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.
14016															
1976	18	0.000	0.003	18	0.003	0.011	18	0.41	1.17	18	0.6	1.6	18	0.2	0.4
1977	21	0.000	0.002	21	0.008	0.025	21	0.31	0.58	21	0.6	1.8	21	0.2	0.6
1978	26	0.001	0.003	26	0.007	0.019	26	0.50	1.38	26	0.9	3.2	26	0.1	0.4
1979	35	0.001	0.004	35	0.002	0.010	35	0.39	1.01	35	0.8	2.9	35	0.2	0.6
1980	25	0.001	0.004	25	0.002	0.009	25	0.44	0.96	25	0.6	1.8	25	0.1	0.4
1981	124	0.001	0.004	124	0.003	0.014	124	0.19	1.59	124	0.6	2.6	124	0.1	0.3
1982	338	0.001	0.004	328	0.002	0.116	339	0.28	1.71	308	0.4	3.1	328	0.1	0.4
1983	339	0.001	0.004	332	0.002	0.015	339	0.34	1.72	339	0.5	3.6	340	0.1	0.4
1984	332	0.001	0.006	332	0.003	0.038	332	0.43	2.91	332	0.5	2.7	332	0.1	0.3
1985	336	0.001	0.006	336	0.006	0.036	336	0.39	2.36	336	0.5	3.0	336	0.1	0.2
1986	340	0.001	0.006	340	0.004	0.067	340	0.21	0.82	340	0.4	2.0	340	0.0	0.2
1987	339	0.001	0.007	339	0.006	0.020	339	0.23	0.97	339	0.5	2.3	339	0.0	0.4
14030															
1978	11	0.002	0.004	11	0.007	0.019	11	0.37	0.98	11	1.2	2.2	11	0.3	0.9
1979	50	0.001	0.004	50	0.007	0.022	50	0.32	1.36	55	0.6	2.2	54	0.1	0.4
1980	52	0.001	0.004	52	0.003	0.023	52	0.47	2.34	52	0.5	1.5	52	0.1	0.3
1981	58	0.001	0.009	58	0.005	0.053	58	0.17	0.56	58	0.7	4.5	58	0.1	1.4
1982	58	0.001	0.002	55	0.003	0.010	58	0.11	0.29	48	0.5	3.5	56	0.1	0.7
1983	54	0.001	0.004	55	0.003	0.018	57	0.17	0.45	57	0.4	1.4	57	0.1	0.2
1984	55	0.001	0.002	55	0.005	0.026	55	0.18	0.49	55	0.4	2.0	55	0.1	0.4
1985	58	0.001	0.004	58	0.007	0.055	58	0.11	0.25	58	0.5	3.0	58	0.1	0.1
1986	53	0.000	0.003	53	0.004	0.021	53	0.10	0.26	53	0.4	1.4	53	0.0	0.1
1987	59	0.000	0.002	59	0.007	0.020	59	0.07	0.17	59	0.4	2.5	59	0.0	0.1

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1987.

Station and Year	Cadmium # of Samples	Cadmium Avg.	Cadmium Max.	Chromium # of Samples	Chromium Avg.	Chromium Max.	Copper # of Samples	Copper Avg.	Copper Max.	Iron # of Samples	Iron Avg.	Iron Max.	Lead # of Samples	Lead Avg.	Lead Max.
14031															
1978	12	0.002	0.003	12	0.004	0.008	12	0.44	1.00	12	0.7	1.3	12	0.1	0.3
1979	54	0.001	0.005	54	0.010	0.189	54	0.25	0.97	58	0.5	2.7	54	0.1	0.4
1980	54	0.001	0.004	54	0.005	0.030	54	0.13	0.26	54	0.5	2.2	54	0.1	0.3
1981	58	0.001	0.003	58	0.005	0.035	58	0.15	0.95	58	0.6	2.6	58	0.1	0.2
1982	54	0.000	0.002	56	0.004	0.010	58	0.13	0.29	50	0.5	3.7	56	0.1	0.6
1983	55	0.001	0.001	53	0.002	0.012	55	0.25	1.54	55	0.6	2.3	55	0.1	0.3
1984	50	0.001	0.002	50	0.004	0.032	50	0.14	0.37	50	0.5	1.9	50	0.1	0.1
1985	55	0.001	0.004	55	0.007	0.029	55	0.06	0.13	55	0.6	2.3	55	0.1	0.1
1986	50	0.000	0.003	50	0.006	0.024	50	0.07	0.16	50	0.3	1.1	50	0.0	0.1
1987	56	0.000	0.002	56	0.006	0.015	56	0.05	0.12	56	0.4	2.3	56	0.0	0.1
14064															
1981	57	0.001	0.004	57	0.003	0.013	57	0.17	0.86	57	0.7	2.3	59	0.1	0.6
1982	52	0.001	0.008	47	0.002	0.009	52	0.21	1.66	53	0.7	2.9	50	0.2	1.1
1983	57	0.001	0.003	57	0.002	0.009	57	0.62	2.50	57	0.7	1.8	56	0.2	0.6
1984	57	0.001	0.002	57	0.002	0.015	57	0.43	2.00	57	0.5	1.7	57	0.2	0.3
1985	57	0.001	0.003	57	0.006	0.012	57	0.11	0.39	57	0.6	2.3	57	0.1	0.3
1986	57	0.000	0.002	57	0.005	0.023	57	0.20	0.64	57	0.5	1.5	57	0.1	0.3
1987	59	0.001	0.004	59	0.005	0.010	59	0.23	1.02	59	0.5	2.6	59	0.1	0.2
14152															
1987	87	0.000	0.006	87	0.009	0.030	87	0.09	0.28	87	1.8	12.6	87	0.1	0.5
14153															
1987	81	0.000	0.011	81	0.009	0.020	81	0.14	0.50	81	1.1	5.5	81	0.1	0.7

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1987.

Station and Year	Manganese # of Samples	Manganese Avg.	Manganese Max.	Nickle # of Samples	Nickle Avg.	Nickle Max.	Nitrate # of Samples	Nitrate Avg.	Nitrate Max.	Sulphate # of Samples	Sulphate Avg.	Sulphate Max.	Vanadium # of Samples	Vanadium Avg.	Vanadium Max.
14016															
1976	8	0.01	0.04	18	0.031	0.013	96	4.0	20.0	105	8.7	33.4	18	0.00	0.02
1977	21	0.03	0.09	21	0.022	0.165	54	3.7	27.8	54	10.0	24.6	21	0.01	0.08
1978	26	0.02	0.06	26	0.016	0.194	53	4.6	24.6	53	11.2	35.3	26	0.00	0.10
1979	35	0.02	0.07	35	0.008	0.042	56	5.4	14.8	56	12.4	41.0	35	0.00	0.01
1980	25	0.02	0.10	25	0.010	0.064	56	4.8	11.4	56	11.5	25.1	25	0.01	0.10
1981	124	0.02	0.12	124	0.005	0.045	128	4.2	13.5	126	8.7	37.0	124	0.01	0.08
1982	339	0.01	0.10	339	0.006	0.100	339	3.5	23.3	339	9.3	48.7	338	0.01	0.14
1983	339	0.01	0.12	328	0.005	0.031	340	3.1	9.5	340	8.4	46.0	339	0.01	0.21
1984	322	0.02	0.51	327	0.006	0.054	332	3.2	16.2	320	7.8	33.5	332	0.01	0.08
1985	336	0.02	0.12	336	0.006	0.037	336	2.9	20.7	336	7.0	22.2	336	0.01	0.09
1986	340	0.01	0.12	340	0.003	0.041	339	3.6	18.6	339	7.8	21.1	340	0.01	0.12
1987	339	0.02	0.20	339	0.008	0.080	339	4.1	19.7	339	9.7	42.0	339	0.02	0.40
14030															
1978				11	0.009	0.013									
1979	45	0.01	0.05	50	0.006	0.032							45	0.00	0.02
1980	50	0.01	0.08	52	0.004	0.026							50	0.00	0.01
1981	51	0.02	0.10	56	0.004	0.034							51	0.01	0.03
1982	57	0.01	0.07	58	0.003	0.009							58	0.01	0.02
1983	56	0.01	0.03	56	0.002	0.009							57	0.00	0.02
1984	55	0.01	0.05	51	0.004	0.046							55	0.00	0.06
1985	58	0.02	0.09	58	0.005	0.017							58	0.01	0.02
1986	53	0.01	0.05	53	0.003	0.032							53	0.01	0.03
1987	59	0.01	0.06	59	0.005	0.010							59	0.01	0.06

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1987.

Station and Year	Manganese # of Samples	Manganese Avg.	Manganese Max.	Nickle # of Samples	Nickle Avg.	Nickle Max.	Nitrate # of Samples	Nitrate Avg.	Nitrate Max.	Sulphate # of Samples	Sulphate Avg.	Sulphate Max.	Vanadium # of Samples	Vanadium Avg.	Vanadium Max.
14031															
1978				28	0.016	0.057							46	0.00	0.01
1979	46	0.02	0.07	54	0.009	0.171							47	0.01	0.02
1980	52	0.02	0.11	54	0.005	0.021							52	0.01	0.02
1981	52	0.02	0.14	58	0.004	0.020							58	0.00	0.02
1982	57	0.01	0.05	55	0.003	0.013							55	0.00	0.03
1983	55	0.01	0.04	55	0.002	0.016							50	0.00	0.03
1984	50	0.02	0.05	50	0.004	0.039							55	0.01	0.03
1985	55	0.02	0.05	55	0.005	0.018							50	0.01	0.13
1986	50	0.01	0.04	50	0.002	0.011							56	0.02	0.05
1987	56	0.01	0.06	56	0.006	0.030									
14064															
1981	57	0.02	0.07	57	0.008	0.056	57	4.7	16.2	57	10.9	29.5	57	0.02	0.12
1982	52	0.03	0.21	53	0.009	0.067	51	4.3	15.6	51	10.3	32.6	52	0.01	0.11
1983	57	0.03	0.13	45	0.007	0.053	57	4.8	16.2	57	11.2	29.7	57	0.02	0.17
1984	57	0.02	0.14	57	0.005	0.037	57	3.5	15.8	57	8.0	19.9	57	0.01	0.10
1985	57	0.03	0.21	57	0.007	0.027	57	3.3	10.1	57	7.5	25.8	57	0.01	0.06
1986	57	0.02	0.12	57	0.004	0.030	57	3.6	10.7	57	8.2	23.8	57	0.01	0.09
1987	59	0.03	0.16	59	0.008	0.040	59	3.7	10.6	59	8.3	18.1	59	0.02	0.09
14152															
1987	87	0.10	0.80	87	0.012	0.160	40	4.6	13.5	40	10.7	20.9	87	0.02	0.16
14153															
1987	81	0.08	0.98	81	0.009	0.050	32	4.5	12.1	32	10.5	25.9	81	0.02	0.19

Table A4. Concentrations (ug/m³) of various constituents of suspended particulates: 1976 to 1987.

Station and Year	Total Carbon			Free Carbon			Carbonate Carbon		
	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.	# of Samples	Avg.	Max.
14152 1987	87	9.6	38.5	87	2.9	14.5	86	0.3	2.4
14153 1987	81	7.1	19.4	81	2.3	7.1	81	0.2	2.4

APPENDIX 4

TOTAL REDUCED SULPHUR

CARBON MONOXIDE, OXIDES OF NITROGEN, HYDROCARBONS AND OZONE

Table A5. Summary of data for total reduced sulphurs, carbon monoxide, oxides of nitrogen and hydrocarbons.

Pollutant and Criteria	Station Number	Year 1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Total reduced sulphur											
Annual average (ppm)	14064	0.001	0.000	0.000	0.001 (b)						
Percentage of values above 1-hour criterion (a)	14064	0.00	0.00	0.02	0.19 (b)						
Carbon Monoxide											
Annual average (ppm)	14064	0	0	0	0	0	0	0	0	0	0
Percentage of values above 1-hour criterion	14064	0	0	0	0	0	0	0	0	0	0
Percentage of values above 8-hour criterion	14064	0	0	0	0	0	0	0	0	0	0

Note: (a) Criterion for hydrogen sulphide (0.02 ppm)
(b) 4 months of data

Table A5. continued
Summary of data for total reduced sulphurs, carbon monoxide, oxides of nitrogen and hydrocarbons.

Pollutant and Criteria	Station Number	Year 1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Nitric oxide											
Annual average (ppm)	14064	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Nitrogen dioxide											
Annual average (ppm)	14064	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Percentage of values above 1-hour criterion	14064	0	0	0	0	0	0.01	0	0	0	0
Percentage of values above 24-hour criterion	14064	0	0	0	0	0	0	0	0	0	0
Total oxides of nitrogen											
Annual average (ppm)	14064	0.02	0.03	003	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Total hydrocarbons											
Annual average (ppm)	14064	2.0	1.6	2.0	2.0	2.0	2.1	2.1	1.9	2.0	1.7

Table A6. Summary of data for ozone

Station and Parameter	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Station 14064											
Annual average (ppm)	0.022	0.021	0.023	0.023	0.023	0.023	0.021	0.022	0.023	0.018(a)	
Number of values above 1-hour criterion	44	30	47	80	116	56	67	68	130	56(a)	
Percentage of values above 1-hour criterion	0.5	0.4	0.6	1.0	1.4	0.7	0.8	0.8	1.6	1.4(a)	
Station 14118											
Annual average (ppm)	0.026	0.024	0.028	0.026	0.019	0.023	0.023	0.022	0.027	0.029	0.027
Number of values above 1-hour criterion	133	41	25	120	16	10	85	39	138	249	182
Percentage of values above 1-hour criterion	1.6	0.5	0.6(a)	1.6	0.2	0.1	1.0	0.5	1.7	3.5	2.6

Note: (a) based on 6 months data